In Patent Application Serial No. 10/812,591
Filed March 29, 2004

DECLARATION OF YOSHI ONO

I, Yoshi Ono, PhD, hereby declare as follows:

1. My residence address is 2526 NW 24th Circle, Camas, WA 98607.

2. Since November of 1992, I have been employed by Sharp Microelectronics Technology (SMT) and Sharp Laboratories of America (SLA), Inc., 5700 N.W. Pacific Rim Boulevard, Camas, Washington 98607. My title is Manager. My responsibilities include directing and supervising research and development efforts related integrated circuit technology, development of fabrication processes and characterization of materials and devices.

3. My educational background includes a BS from the University of Southern California and a PhD from Iowa State University.

4. Prior to my employment with SMT/SLA, I worked at United Memories, Inc. of Colorado Springs, CO and at Tektronix Inc. in Beaverton, OR.

5. I have written 32 scientific articles that have appeared in journals such as Applied Physics Letters and Journal of Chemical Physics. I am of the inventor or co-inventor of 38 issued patents. A complete list of my publications and issued patents is attached.

6. I have read the claims and relevant portions of the specification for the patent application at issue, Serial No. 10,812,591, entitled "High Density Plasma Process for the Formation of Silicon Dioxide on Silicon Carbide Substrates", invented by Pooran Joshi, Apostolos Voutsas, and John Hartzell, who I will subsequently refer to as the Applicant. I have also read the Office Action of January 18, 2006, where the Applicant's

claims 1-6, 9, 18, and 32 have been rejected as anticipated by US 2004/0129673 (Belyansky), claims 7-8 and 19-23 have been rejected as obvious by Belyansky, claims 10-14, 18, 24-30 have been rejected as obvious by the combination of Belyansky and US 2003/0059556 (Ouellet), claims 15-17 have been rejected as obvious by the combination of Belyansky, Ouellet, and US 4,888,820 (Chen), and claim 31 has been rejected as obvious by the combination of Belyansky and US 5,125,885 (Furukawa). I have read the relevant sections from all the prior art references.

7. It is my opinion as a person of skill in the field of IC processing that the prior art references mentioned above in Section 6 do not anticipate or make Applicant's claims obvious. There are key features in the Applicant's independent claims (amended claim 1, claim 32, and new claims 33-38), which are not particularly described in any of the prior art references. Further, there is no discussion in the prior art references to lead an expert such as myself to think of these unspecified limitations. In fact, there is no discussion in these references to lead an expert to think that the Applicant's limitations might even be desirable.

8. Belyansky describes a high-density (HD) plasma process for oxidizing a substrate, made from either a conductor or semiconductor material, at a relatively low substrate temperature. Belyansky presents a long list of possible substrate materials in paragraph 26. Belyansky does not describe a use or structure associated with his oxidation process. In paragraph 28, Belyansky states that his "inventive method" grows thermal oxide. I find this statement confusing - Belyansky does not disclose any high temperature process, but thermal oxide is, by definition, an oxide formed at a high temperature. Neither does Belyansky disclose any metrics associated with a high-quality

thermal oxide. Further, Belyansky's primary goal appears to be forming oxide at high growth rates. All these factors suggest to me that Belyansky's process is primarily associated with forming bulk or field-grade oxide. Process details are presented in paragraph 29. Belyansky's process relies upon a gas mixture that contains at least 20% oxygen. The oxygen gas is preferably mixed with Ar, while light noble gases such as He are not preferred. As described in more detail below, these gas ratios support a high oxide growth rate of 0.25 to 1Å/sec.

9. Unlike Belyansky, the Applicant's process is based upon an understanding that the inert gas/O_2 ratio is strongly correlated to the generation of radicals. Inert gas metastables are more effective in generating oxygen radicals (excited oxygen atoms) at high inert gas dilutions exceeding 90%. A higher oxygen dilution (>20%), such as described by Belyansky, results in an enhanced quenching of the oxygen radicals, and the generation of more ions, which can also oxidize Si. However, the quality of the films is degraded due to bombardment by ionized oxygen species. An O_2 concentration below 10% promotes the radical-induced growth of high quality (high electrical performance and high reliability) oxide on a Si-containing substrate, as O_2 is the main quencher of the metastable inert gas atoms that are required for the generation of oxygen radicals. The above-mentioned difference between the Applicant's and Belyansky's processes are featured in claims 34 and 35. Claim 34 specifically recites an oxygen ratio of less than 10%, while claim 35 describes characteristics that are conventionally only associated with a high-temperature thermal oxidation processes. Belyansky's oxide film is inherently low quality due to the ionized oxygen species bombardment, which is a result of a high (greater than 20%) ratio of oxygen in the gas mixture.

10. The Applicant's process also recognizes that among the following three inert gases: He, Ar, and Kr, that He is the most suitable gas for enhancing oxygen radical concentration in the plasma, and minimizing plasma induced film damage, which can be critical for device performance. The first metastable energy states of He, Ar, and Kr are 19.8 eV, 11.6 eV, and 9.9 eV, respectively. Therefore, He is the most effective gas for the generation of oxygen radicals by energy transfer. The concentration of the metastable atoms strongly depends on the O_2 concentration (as mentioned above in Section 9), as O_2 is the main quencher of the metastable atoms. Hence, it is important to maintain the O_2 concentration below 10% so that the metastable inert atoms are not quenched by the O_2. So a combination of He inert gas (lightest among the three gases), with a low O_2 concentration (<10%), promotes oxygen radical-induced growth of high quality oxide on a Si-containing substrate. He gas is also the most suitable to minimize any plasma-induced damage to the growing film, as it is lightest among the inert gases under consideration. The oxide growth rates in various inert gases, as shown in Fig. 9 of the Applicant's specification, clearly demonstrate this point.

Belyansky does not consider He gas to be any significance because his focus is on a process range where the O_2 concentration is more than 20%. Belyansky prefers Kr and Ar gases, because these gases are associated with higher growth rates, when the oxygen concentration is greater than 20%. At O_2 concentrations of greater than 10%, O_2 is the major quencher of the metastable inert gas atoms that can efficiently generate oxygen radicals. So at O_2 concentrations of greater than 10%, the growth process is dominated by ionized oxygen species. The heavier inert gas atoms (Kr and Ar) are more effective in ionizing O_2 gas, as compared to a very light gas such as He. Belyansky's claim to high

growth rates associated with Kr and Ar atmospheres, fails to show and understanding of the correlation between He gas and oxygen radicals (generated at low O_2 concentrations), or an appreciating that an HD plasma process can be used to fabricate high electrical quality films suitable for electronic device applications. These distinctions between Belyansky and the Applicant's process are presented in claim 1, where a gas mixture of He and oxygen is specifically recited.

11. The growth rates described in the Applicant's process are significantly lower than the rates described by the Belyansky, as the Applicant's focus is on the growth of high electrical quality oxide thin films by oxygen radicals, which dominantly control the oxidation process at concentration levels below 10%. At oxygen concentrations above 10%; the higher oxygen levels increasingly quench the inert gas metastables and ionic oxygen species dominantly control the growth kinetics. Additionally, Belyansky high growth rates are predicated upon the use of heavier gases, such as Kr and Ar, to efficiently ionize the O_2 gas by collisions. While oxygen ions can oxidize silicon, they are not desirable for processes that fabricate high electrical quality oxide thin films.

In summary, Belyansky has found that the highest growth rates can be found when an oxygen concentration of greater than 20% is used. When using the higher oxygen concentration, Belyansky has found that the growth rates can be optimized (increased) by using Ar or Kr as a mixing gas. On the other hand, the Applicant's process focuses on the growth of high quality (electrical quality and reliability) oxide using oxygen radicals that are promoted when the oxygen concentration is kept below 10%. At oxygen concentrations below 10%, He gas promotes a higher oxide growth rate than either Ar or Kr. He metastables have the highest energy among the three gases (He,

Ar, and Kr) so it is the most efficient in supporting oxide growth when the O_2 concentrations are below 10%. As noted above, this is because the metastable atomic concentration is not quenched by O_2, and radicals are efficiently generated by the metastable atoms of the inert gas. Since He is a lighter gas, its use minimizes any plasma-induced thin film damage, in both the bulk of the film and at interface with the underlying layer. While the Applicant's growth rates are lower than Belyansky's bulk oxide process, they are still practical for commercial fabrication, and they have the advantage of producing a higher quality product with more uses than bulk oxide. These distinctions between Belyansky's and the Applicant's processes are presented in claim 37, where a growth rate of 10 Å per minute is recited.

10. The growth of oxide on a SiC substrate consumes Si, but leaves excess C at the interface which is detrimental to device performance. The Applicants describe an approach to minimize C content at the interface, by using highly active oxygen radicals to convert C to CO. The Applicant's CO conversion process minimizes damage to the interface using a high conversion efficiency and a low thermal budget. Conventional thermal oxidation processes are very inefficient due to molecular state of the oxygen. Therefore, the thermal budget is high (T>800 °C). Plasma processes dominated by ionic oxygen species, such as the one described by Belyansky, with an O_2 concentration >20%, do not have high efficiency and lead to substantial interface damage by the impinging ionic species. On the other hand, the Applicant's process generates active oxygen radicals, by keeping the oxygen concentration below 10%, to effectively remove C by oxidation at low temperatures, while minimizing any damage to the film. These distinctions between Belyansky's and the Applicant's process are presented in claim 33,

which describes the bonding free C atoms in the SiC substrate with the reactive oxygen species, to form CO.

12. Viewed from a different perspective, the Applicant's process efficiently oxidizes SiC by breaking Si-C bonds, and reacting oxygen radicals with Si to form SiO_2. Additionally, the interface equality, which is critical for electronic devices, is maintained by efficiently removing C by conversion to CO, and minimizing plasma-induced damage to the SiC surface and the growing film, as a result of the oxygen radical dominated process. Plasma processes such as Belyansky's, which are dominated by ionic oxygen species, are less efficient in removing C and lead to film damage by the bombarding ionic species. These distinctions are presented in claim 32, which recites breaking the Si-C bonds in the SiC substrate, and bonding free Si atoms to the HD plasma-generated reactive oxygen species.

13. The Applicant's present a process variation that uses a high-density PECVD (HD-PECVD) process to deposit an oxide film over a SiC substrate, as opposed to plasma oxidizing the substrate. This approach can form a high quality oxide film, without consuming the SiC substrate or damaging the SiC surface. The HD-PECVD process deposits high quality SiO_2 films, which does not lead to any appreciable damage to the interface quality as is reflected in the claims 15, 16, 17, and 35.

Claim 36 describes the deposition of silicon dioxide over the SiC substrate using an HD-PECVD process. Claim 38 describes the formation of a silicon dioxide layer overlying the SiC substrate, followed by HD plasma process to oxide the deposited silicon dioxide layer. Belyansky does not address the subject of HD-PECVD, or the oxidation of a silicon dioxide layer that has been deposited overlying a SiC substrate.

The Office Action, on page 6 (the rejection of claims 19 and 20) states that it would have been obvious for Belyansky to deposit a Si layer overlying the SiC substrate because silicon dioxide can be formed by oxidizing a thin Si layer. Here, the Examiner fails to appreciate that there is a difference between oxidation and deposition processes. While both processes form a silicon oxide product, the oxidation process grows silicon oxide from an underlying Si film, while the deposition process deposits silicon oxide without consuming the underlying Si film.

14. The Ouellet reference describes the fabrication of an optical quality silicon oxide. A good optical quality film does not guarantee good electrical performance. Electrical performance is strongly dictated by the bulk quality of the film and its interface with the underlying film. If either the interface quality or the bulk film quality is poor, the overall device performance will be poor. The combination of the basic plasma characteristics, process conditions and range, and plasma-induced bulk/interface damage are critical to forming a high electrical quality film.

Further, Ouellet describes a PECVD process that relies upon a high substrate temperature to further chemical reactions, as opposed to an HD-PECVD process, which is a low temperature process that relies upon the kinetic energy of the oxygen radicals or ions to provide energy to the process. Ouellet does not teach a high-density plasma or HD-PECVD process.

As a person skilled in the art, I do not see how Ouellet's PECVD process suggests any modifications to Belyansky's plasma oxidation process. Put another way, the combination of Belyansky and Ouellet do not suggest the use of an HD-PECVD process to deposit a silicon dioxide layer over a SiC substrate.

15. As general background, Chen presents some metrics commonly associated with judging the quality of a silicon oxide film. Chen provides no guidance as to how these characteristics are to be achieved. More particularly, Chen provides no guidance as to how these characteristics can be achieved when using an HD plasma oxidation process.

16. Furukawa teaches the formation of a metal-semiconductor contact formed by etching holes in a CVD or PECVD deposited oxide film overlying a SiC film. However, since Furukawa does not describe the etching of a silicon dioxide film formed through a plasma oxidation process, Furukawa does not offer any obvious modifications to Belyansky's plasma oxidation process. That is, neither Belyansky nor Furukawa suggest that a CVD or PECVD oxide can be treated the same as a plasma oxidized silicon oxide film.

17. In summary, it is my opinion that the Belyansky reference does not specifically describe every feature of the Applicant's claims. It is my opinion that the secondary references cited in the Office Action do not bring to mind any changes to Belyansky that would make all the features of the Applicant's independent claims obvious. More generally, I do not see any compelling crossover being Furukawa, Ouellet, Chen, and the primary (Belyansky) reference. Rather, it appears to me that the references were combined merely as a result of a keyword search. I believe that an expert is unlikely to "merge" ideas from references working in different fields, as are the cited references. In this case, I believe that it would have been more proper to combine Belyansky with references working in the field of HD plasma processes.

18. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United State Code and that such willful, false statements may jeopardize the validity of the application on any patent issuing thereon.

Date: 3/28/2006 Signed: 

Yoshi Ono

Publications and Patent list for Yoshi Ono of Sharp Labs of America

As of March 28, 2006

Publications

Directed integration of ZnO nanobridge devices on a Si substrate
John F. Conley, Jr., Lisa Stecker, and Yoshi Ono
Appl. Phys. Lett. 87, 223114 (2005)

Dielectrophoretically Controlled Fabrication of Single-Crystal Nickel Silicide Nanowire Interconnects
Lifeng Dong, Jocelyn Bush, Vachara Chirayos, Raj Solanki, Jun Jiao, Yoshi Ono, John F. Conley, Jr., and Bruce D. Ulrich
Nano Lett. 5, 2112 (2005)

NbO as gate electrode for n-channel metal-oxide-semiconductor field-effect-transistors
W. Gao, J. F. Conley, Jr., and Y. Ono
Appl. Phys. Lett. 84, 4666 (2004)

Low-Temperature Growth of Thermal Quality SiO_2 Thin Films in High-Density He/O_2 Plasma Generated by RF Driven ICP Source
P. C. Joshi, Y. Ono, A. T. Voutsas, and J. W. Hartzell
Electrochem. Solid-State Lett. 7, G62 (2004)

Densification and improved electrical properties of pulse-deposited films via in situ modulated temperature annealing
J. F. Conley, Jr., Y. Ono, and D. J. Tweet
Appl. Phys. Lett. 84, 1913 (2004)

Pulsed deposition of metal–oxide thin films using dual metal precursors
J. F. Conley, Jr., Y. Ono, D. J. Tweet, and R. Solanki
Appl. Phys. Lett. 84, 398 (2004)

Pulsed deposition of silicate films
W. He, R. Solanki, J. F. Conley, Jr., and Y. Ono
J. Appl. Phys. 94, 3657 (2003)

Electrical properties of HfO_2 deposited via atomic layer deposition using $Hf(NO_3)_4$ and H_2O
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Atomic layer deposition of thin hafnium oxide films using a carbon free precursor
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Appl. Phys. Lett. 79, 1661 (2001)

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G.Y. Yeom, Y. Ono, and T. Yamaguchi
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A study of the unimolecular decomposition of the $(C_2H_4)_3^+$ complex

W.-B. Tzeng, Y. Ono, S. H. Linn, and C. Y. Ng
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A study of the unimolecular decompositions of the $(C_3H_6)_2^+$ and $(c\text{-}C_3H_6)_2^+$ complexes
W.-B. Tzeng, Y. Ono, S. H. Linn, and C. Y. Ng
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J. Chem. Phys. 80, 1482 (1984)

A study of the unimolecular decomposition of the $(C_2H_2)_2^+$ complex
Y. Ono and C. Y. Ng
J. Chem. Phys. 77, 2947 (1982)

Higher resolution photoionization study of acetylene near the threshold
Y. Ono, E. A. Osuch, and C. Y. Ng
J. Chem. Phys. 76, 3905 (1982)

The heat of formation of C_2H^+
Y. Ono and C. Y. Ng
J. Chem. Phys. 74, 6985 (1981)

Molecular beam photoionization study of CO, N_2, and NO dimers and clusters
S. H. Linn, Y. Ono, and C. Y. Ng
J. Chem. Phys. 74, 3342 (1981)

A study of the ion–molecule half reactions $O_2^+ (a\ ^4\Pi_{u,v})\cdots(O_2)_m \rightarrow O^+_{2m+1} + O$, m = 1, 2, or 3, using the molecular beam photoionization method
S. H. Linn, Y. Ono, and C. Y. Ng
J. Chem. Phys. 74, 3348 (1981)

Molecular beam photoionization study of OCS, $(OCS)_2$, $(OCS)_3$, and $OCS{\cdot}CS_2$
Y. Ono, E. A. Osuch, and C. Y. Ng
J. Chem. Phys. 74, 1645 (1981)

A study of the high Rydberg state and ion–molecule reactions of carbon disulfide using the molecular beam photoionization method
Y. Ono, S. H. Linn, H. F. Prest, M. E. Gress, and C. Y. Ng
J. Chem. Phys. 74, 1125 (1981)

Higher resolution photoionization study of NO near the threshold
Y. Ono, S. H. Linn, H. F. Prest, C. Y. Ng, and E. Miescher
J. Chem. Phys. 73, 4855 (1980)

Molecular beam photoionization study of carbon disulfide, carbon disulfide dimer and clusters
Y. Ono, S. H. Linn, H. F. Prest, M. E. Gress, and C. Y. Ng
J. Chem. Phys. 73, 2523 (1980)

A study of the chemiionization process $CS_2^*(n) + CS_2 \rightarrow CS_3^+ + CS + e^-$ using the molecular beam photoionization method
M. E. Gress, S. H. Linn, Y. Ono, H. F. Prest, and C. Y. Ng
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Patents

7,015,138	Multi-layered barrier metal thin films for Cu interconnect by ALCVD
6,998,317	Method of making a non-volatile memory using a plasma oxidized high-k charge-trapping layer
6,930,059	Method for depositing a nanolaminate film by atomic layer deposition
6,902,960	Oxide interface and a method for fabricating oxide thin films
6,875,677	Method to control the interfacial layer for deposition of high dielectric constant films
6,873,048	System and method for integrating multiple metal gates for CMOS applications
6,861,712	MOSFET threshold voltage tuning with metal gate stack control
6,858,514	Low power flash memory cell and method
6,833,572	Electrode materials with improved hydrogen degradation resistance
6,825,106	Method of depositing a conductive niobium monoxide film for MOSFET gates
6,780,700	Method of fabricating deep sub-micron CMOS source/drain with MDD and selective CVD silicide
6,737,693	Ferroelastic integrated circuit device
6,720,258	Method of fabricating a nickel silicide on a substrate
6,689,646	Plasma method for fabricating oxide thin films
6,686,212	Method to deposit a stacked high-κ gate dielectric for CMOS applications
6,632,731	Structure and method of making a sub-micron MOS transistor
6,627,503	Method of forming a multilayer dielectric stack
6,616,857	C-axis oriented lead germanate film
6,590,243	Ferroelastic lead germanate thin film and deposition method
6,573,134	Dual metal gate CMOS devices and method for making the same

6,551,947	Method of forming a high quality gate oxide at low temperatures
6,534,871	Device including an epitaxial nickel silicide on (100) Si or stable nickel silicide on amorphous Si and a method of fabricating the same
6,495,378	Ferroelastic lead germanate thin film and deposition method
6,483,137	Capacitor utilizing c-axis oriented lead germanate film
6,468,901	Nickel silicide including iridium for use in ultra-shallow junctions with high thermal stability and method of manufacturing the same
6,440,752	Electrode materials with improved hydrogen degradation resistance and fabrication method
6,420,279	Methods of using atomic layer deposition to deposit a high dielectric constant material on a substrate
6,410,346	Method of forming ferroelastic lead germanate thin films
6,410,343	C-axis oriented lead germanate film and deposition method
6,407,435	Multilayer dielectric stack and method
6,403,453	Dose control technique for plasma doping in ultra-shallow junction formations
6,348,373	Method for improving electrical properties of high dielectric constant films
6,297,539	Doped zirconia, or zirconia-like, dielectric film transistor structure and deposition method for same
6,207,589	Method of forming a doped metal oxide dielectric film
6,200,866	Use of silicon germanium and other alloys as the replacement gate for the fabrication of MOSFET
6,190,925	Epitaxially grown lead germanate film and deposition method
6,184,110	Method of forming nitrogen implanted ultrathin gate oxide for dual gate CMOS devices
6,060,755	Aluminum-doped zirconium dielectric film transistor structure and deposition method for same